The Design of FACET to Support Use by Airline Operations Centers

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Abstract

NASA's FACET (Future ATM Concepts Evaluation Tool) is a software package that predicts air traffic patterns. Such predictions are of potential value to a number of decision makers in the National Airspace System (NAS), including FAA traffic managers and airline dispatchers. In the study to be reported here, data was collected to:

- Identify uses of the functions embedded in FACET for Airline Operations Centers (AOCs)
- Determine enhancements of FACET (in terms of its underlying functionality or its interface) that might better support the needs of dispatchers and air traffic control coordinators at AOCs.

To address these goals, a series of structured interviews with practicing airline dispatchers were conducted. As part of these interviews, the participants were introduced to the current capabilities of FACET and asked to consider:

- Potential uses of the functionality contained in FACET for AOCs
- Potential extensions of the functionality of FACET to enhance its use by AOCs
- Potential enhancements in the interface design of FACET to better support AOC tasks.

A total of 19 dispatchers were interviewed, representing experience at 5 different airlines and the US Air Force. The findings fall into five categories:

- AOC tasks that could make use of FACET
- Using FACET to predict which flights will be moved by ATC/TFM
- Adapting FACET to support different AOC/Dispatch strategies
- Combining FACET trajectory predictions with other available data
- Developing task-specific interface designs to support AOCs.

AOC Tasks that Could Use FACET

FACET was designed to predict air traffic congestion. The question addressed by this study was how its design could be enhanced to support tasks performed by dispatchers and ATC coordinators at AOCs.

The study identified a variety of AOC tasks in which information provided by FACET would be potentially useful. These included using FACET to help:

- Evaluate traffic constraints along alternative routes for a single flight during preflight planning. As an example, consider the following exchange that emphasizes the potential value of predictions: "Where this becomes much more critical is on the long-haul flights where we're looking at an LA-Baltimore and we had a [737]-700 that crapped out and we substituted a -300 for a -700. We're looking at just bare bones fuel to get there. As it becomes more operationally critical with respect to fuel, we lean on more information to do certain things like instill confidence in the crews. You plan to be in Baltimore from LA with 5500 pounds over destination, but some of these crews will what-if you to death. So if we could instill come confidence in the crews and the dispatchers about the tools that they have, we might be able to better satisfy their concerns. ... The data needs to be looking out that far."
- Identify modifications to a flight plan (route, altitude profile, departure time, speed) that would avoid a traffic constraint.
- If a flight needs to be diverted to one of 2-3 possible alternates, answer the question

regarding which of the alternatives best avoids air traffic congestion while flying there. In addition, help determine which of these alternatives offers the best chance of re-dispatching to the original destination in a timely fashion (from the perspective of traffic congestion).

- Evaluate alternative reroutes contained in ATCSCC reroute advisories in terms of traffic constraints.
- Alert the dispatcher if a flight with an already filed flight plan (whether still pre-departure or enroute) is now predicted to encounter traffic constraints.
- Allow an ATC Coordinator to look at the impact of an ATCSCC advisory containing a Playbook Play and assess its impact on all of the airline's flights in terms of encountering traffic congestion.
- Allow an ATC Coordinator or dispatcher to look at the predicted traffic congestion for specific airspace regions (such as the arrival sectors for an airport).
- Allow an ATC Coordinator to model the impacts of alternative Playbook Plays or other types of reroutes in terms of creating or avoiding traffic congestion.
- Allow an ATC Coordinator to analyze how to best meet ATC "reduction objectives" in terms of predicted traffic constraints. If it is decided that a 35% reduction of capacity is needed, then it would be beneficial to consider what filings would "best" achieve this reduction.

Note that some of the uses of FACET involve tactical situations, which are easier to predict in terms of uncertainty in winds and traffic, while others call for longer prediction horizons.

Predicting Movement of Flights

As noted above, FACET was designed to predict air traffic congestion. Although this type of metric would sometimes be of use to AOC staff, in many cases the question they really want to answer is:

How likely is it that this particular flight will be rerouted because of traffic congestion, and if so, what is the reroute (or holding or some other air traffic control maneuver) likely to be?

Discussions of this question indicated that in many cases, this is the question that the dispatcher really needs to have answered, as he needs to decide whether to plan a different route or just plan for contingencies if the flight is likely to be tactically moved by ATC (adding extra fuel, etc.). This contrasts with the potential use of FACET by the FAA to predict controller workload and task complexity in order to guide traffic flow management decisions.

While sector congestion is one factor that determines which flights will be moved, not all flights that are filed through a congested sector are equally likely to be moved. This fact is reflected in statements like the following:

"I need to know whether I am the problem or it just happens that I am there and someone else is the problem."

"Sector volume isn't enough. It depends if they're flying tail to tail or whether they're coming in climbing or descending patterns. What the airline really cares about is whether this guy's going to be moved. So I may hit a very congested sector but that doesn't mean nobody's going through it. What I want to know as an airline is whether my guy going to be allowed through. For the FAA, complexity may be the right measure, because they're concerned about control, but for an airline the fact that a controller is busy and might move me is important, but sector congestion is only one factor that determines who he's moving. There may be other good predictors in addition to sector congestion or volume that may be able to suggest whether my flight is going to be moved or not."

"If I know that my flight is going to be in a stream that is nicely in sequence and you've got other folks who are causing trouble, who's going to be moved is not going to be the flights in the sequence. So in that case I don't care if the sector is red because I've joined the flow before I got to that sector so they are not going to touch me. … You need to see if you can identify streams of traffic and see if you are part of the stream where everybody is flying east to west or whether you are the guy who is going to go through north or south."

"Yellow here means that during that 15 minute period this sector is expected to go over the monitor

alert, but there are some proposed departure flights in there, so all the flights aren't all active. So my airborne flight is probably ok."

"For a stream like flights from St. Louis out of Midway, if it is during one of American's banks coming in from the east and we're a short haul, we know that we are going to get moved over to the west because we're a short haul."

Thus, these statements suggest that there are a variety of factors, in addition to sector volume, that determine whether a particular flight is likely to be moved. These include whether the flight is:

- Already part of a flow or is working against that flow.
- Already airborne.
- A long haul or short haul.
- In a sector with high complexity rather than just a high volume that is well structured and easy to control.

Additional research is needed to determine how such factors could be combined with FACET predictions to identify flights that are likely to be moved.

Dispatch Strategies

As the discussion above highlighted, just because a flight is filed to go through a congested sector does not mean that it will be moved. Thus, an indication by FACET that a flight is likely to go through a busy sector is not by itself sufficient information for the dispatcher to decide whether he should file a different route or leave the flight on the original route through the busy sector. What the dispatcher needs is a sense of how likely the flight is to get moved:

"We have certain flights every day that get moved over."

"Why don't you just file it that way?"

"Because 50% of the time we don't get moved. We will put on extra fuel in case it gets moved, but you've got to figure if you file it that way you have a chance of actually getting it. If the chances are good enough, that makes it worth filing it. Phoenix is the same thing. The same thing happens in Phoenix with the northeast flow because it's America West. Our short hauls [to Phoenix] get moved because the northeast cornerpost is loaded up with an arrival bank. … They will move our shorter hauls. At El Paso they will move them down [to the southeast cornerpost]. If it [the probability of getting moved to the southeast cornerpost] was above 80% I might say screw it [and just file to the southeast cornerpost instead of filing to the northeast cornerpost and letting them decide whether to move me]."

Thus, the decision regarding whether to file a different route depends on how likely the flight is to be moved by ATC/TFM if left on the original route. If that likelihood isn't too high, the dispatcher may instead use a variety of other strategies in response to the predicted red [congested] sector. The range of strategies discussed by the participating dispatchers is summarized below.

Strategy 1. Filing a Different Route

One approach is to actually file a reroute because of predicted traffic congestion:

"I'll put it to you this way. When I work Minneapolis to the East Coast you can go on the pref route which goes down through Chicago airspace or, as a dispatcher, I can make the choice to send them over Green Bay through Canada and bring them through Boston Center. New York Center doesn't like this but I don't get any of the holds enroute. I put a little extra gas on him and he flies to Boston Center. He will stop and hold maybe 5 or 10 minutes in Boston airspace to get into New York. To me that is a better flight plan because it gives me less work because he's not sending me messages all the way across that he is holding in Chicago, he is holding in Cleveland, he is holding in New York. As dispatchers we are trying to lower our workload yet succeed with the flight. If for flights out of Detroit I know Chicago Center is going to be red and I know that Cleveland right at the boundary to New York Center is going to be red, then maybe I should just route the flight differently."

"We had an agreement that we would take the first 6 flights out of Albuquerque to Phoenix down south. So we would fuel them, we would file them down south and then they would run on normal."

"Sometimes you have the choice: Do I want to go to the East side of the line or the West side of the

line. If we had this it would become apparent that West looks better traffic- and weather-wise."

"[In terms of who I want to move], if I've got an airplane coming off of San Francisco that's going to New York through this sector, do I move that one? Economics-wise it is better if I move him when he is in San Francisco than if I wait until he gets to the sector and move him. … It is more economic to do it before it leaves the ground than to wait until it gets to Cleveland's airspace and then have to move it."

"In some cases there is an easy decision because at low cost you can gain a lot of predictability. … If you are coming from Florida you do not have a lot of choice, but if you are coming from Seattle you have the choice of going over Canada."

Strategy 2. Adding Extra Fuel

If it looks like there is a possibility of a reroute, instead of filing a different route for a flight, often the dispatcher will instead simply add additional fuel:

"We have a variety of different things that we can do based on your information. As you know you can delay the flights, you can reroute the flights, you can add additional fuel and continue on a normal route."

"If I'm going to go through traffic I'll just put more gas on it, but if there's weather I'm going to go around."

Strategy 3. Coordinating with TFM

Instead of trying to guess what TFM is going to do, an alternative is to work with them to establish a policy that makes it easier to predict who may be moved:

"We've told them don't grab a long haul. Take a short haul if you've got to take somebody. The long hauls don't have the fuel. Just don't grab one of our longer flights coming in; grab somebody that is still on the ground. What they will do is they will grab it before it reaches the military area, which is a huge reroute because of the military area out in Phoenix. They have to work their way around that."

"If I know this in advance like yesterday that we have these DC9s that are range limited and my options are very limited operationally, I can go to the ATC Coordinator and have him call ATC and get an exception. FACET could provide better information so we can talk to ATC on their terms and say that we'd like them to bend their rules just a little bit for this DC9. That is one of the things that this will allow us to do."

"If you tell me that my DC9 from Hartford to Minneapolis is high on the probability list [to be moved], how about if I offer up my Airbus from Newark to Minneapolis instead? Give me the ability to negotiate. … Green Bay to Eau Clare will get moved north versus the Badger to Eau Clare that comes in a little south because it is less of a move than the Green Bay one. There is another one: San Francisco to Modesto. They have 3 streams of traffic and their solution is usually to move the northern stream … Pull a couple of those aircraft out to go around the north side."

Strategy 4. Changing the Schedule

One strategy for avoiding a reroute is to change the scheduled departure time of a flight so it avoids the peak congestion period:

"The Albuquerque TMO out there told us if you were just 5 minutes behind the pack of airplanes coming down they wouldn't have to move it. Based on that input, we changed the scheduled departure time out of Nashville to try and accommodate that. That has made a difference."

Strategy 5. Airline-Initiated Enroute Changes

In some cases, adjustments to deal with predicted sector congestion can be made tactically:

"We went for a period of time where we had to tell the flight crews that fly that route, don't ask for short cuts, don't try to speed up, slow down. If you can back up 5 minutes, slow down enough to where you get behind the pack, you won't get rerouted."

Strategy 6. Changing a Departure Time

Another strategy is for the airline to deliberately delay the departure of a flight for a short time.

"It [would be nice if FACET could also give us the option to hold that DC9 on ground for 10

minutes so that it wouldn't have that problem [getting an airborne reroute]. We've never had the ability to see that possibility before. We could also push him early."

"[It would be nice to be able to just simply click on that red area [a red sector in FACET] and say, maybe if I just push this thing out 10 minutes later it will no longer be red."

Strategy 7. Changing Altitude

Sometimes it is sufficient to simply change the altitude profile instead of the route in order to avoid an ATC reroute:

"If I am on an airway, is there an altitude change that would solve the problem, ease the pressure?"

"You be able to go down 2000 feet and be out of there."

"You might want a display that shows that, if I am on J48, here's a vertical slice for J48 in terms of congestion."

"Should I descend to 28000 ft to get through there, which would only cost me a couple hundred pounds of fuel? I would rather do that, but I need to know whether that is available."

Strategy 8. Deciding When to Act

Another aspect of the dispatcher's strategy is deciding when to make a change, if any, in the plan for a flight.

"I may wait to see how many others vote for so and so before I vote. ... We wait on the other airlines to move their airplanes so we can see what the demand is going to be. "

Dispatch Strategies – Summary

The previous section discussed the fact that dispatchers are interested in knowing how likely it is that a flight will be rerouted by ATC. This section on Dispatch strategies goes a step further, and emphasizes that the dispatcher has a wide repertoire of responses to deal with a flight that is predicted to go through a sector that is predicted to be congested. The dispatcher could choose to reroute the flight. Alternatively, however, he might choose to simply add extra fuel, change the departure time slightly, etc. Thus, in addition to helping the dispatcher decide how likely it is that a flight will be moved by ATC, the dispatcher would like information about the likely nature and extent of the reroute should the flight be moved by ATC, as well as information about the viability of certain alternatives (such as changing the altitude profile or the departure time).

Combining FACET Trajectory Predictions with Other Data

Philosophically, the dispatchers recommended a human-centered approach that treats FACET as one source of data to help the dispatcher make judgments:

"Show them the data and let the person do the probabilistic reasoning."

The dispatchers interviewed indicated that, to improve prediction accuracy and help the dispatcher make better judgments, three kinds of data could be integrated into FACET:

- Complete 4-D trajectories based on airline flight plans.
- Weather data.
- Historical data about the performance of a flight (such as its history of reroutes).

Complete 4-D Trajectories

The dispatchers noted that the airlines generate full 4-D flight plans that include the complete planned trajectory. If available, this information might add considerably to the accuracy of predictions.

At present, such data is not available through ETMS, as the airlines only file the planned cruise altitude and speed for each flight:

"One of the design issues is that, while FACET may have a 4-D flight plan for that particular flight and a more fancy version might have all the 4-D trajectories for that airline's flights, in the current world, ETMS does not have the information, so that everybody else is going to have to reason based on the less accurate ETMS data, where you just have a cruise altitude and where FACET has to model what the other aircraft are likely to do."

"FACET should be taking the 4-D trajectory from the airline's flight plan computer to decide what sectors a flight is actually going to pass through."

"If they know they are going to stay low through a couple of sectors here, there is no sense in having another model not use the information for the flight that the dispatcher is looking at. So one point of communication is to make use of the original flight plan, because you have it in much better detail, much more accurately than ETMS does."

"The broad issue, in terms of AOCs using FACET, is: What are the minimally accurate data necessary to make these predictions good enough for a dispatcher to pay attention [to]? … We need to know how often we are running into situations where the prediction is far off because in reality everybody is staying down at flight level 230. If the answer is that FACET's predictions are a close enough approximation to make the right decision a lot of the time, then you can live with the current world. If it isn't, then FACET will need more complete flight plans from the airlines, not just cruise altitudes, but really 4-D trajectory information."

Thus, another recommendation is that the FAA should be encouraged to require the filing of complete flight plans in order to support more accurate predictions of sector volume and complexity. In the short run, however, if an individual airline could at least integrate its own flight plans into FACET, then that would help improve the accuracy of the sector congestion predictions for its flights. In terms of the underlying processing, this approach would result in using FACET's trajectory calculations for those flights for which the airline filings were unavailable, because the airline (or other NAS user) has not yet generated the flight plan (or will not be providing it). (Note that real-time information about FAA traffic management initiatives such as miles-in-trail restrictions, altitude capping and ground delay programs could be of similar use to improve predictions.)

Weather Data

The main point regarding these data is that the decision about how to route a flight depends on considerations of weather as well as traffic constraints. Thus, to best support such reasoning, displays of weather and traffic constraints need to be integrated.

Efforts are already underway to explore such efforts for information integration within FACET. The value of such displays was supported by the dispatchers:

"If you want me to make my decision from this display I need weather. I'd like to see an overlay of either current or predicted weather. I like the graphing and the center boundaries and the constrained sectors. Don't give me every NAVAID within Washington Center, but give me those that might be realistic options for me if I'm going to change my route and avoid the sector."

Historical Data

Because there are many factors besides traffic constraints that need to be considered in deciding how to plan a flight, the design of FACET for AOCs needs to think in terms of how to enhance the ability of the dispatcher to judge whether the traffic constraints along some route merit a change in a flight plan. One implication of this is that FACET should provide integrated access to all of the data that could help with such judgments.

One important category of such data is historical data about what happened to the flight when a given plan was filed:

"If we knew that two sectors in Cleveland are congested terribly and are going to cause back ups everyday from 7:00 a.m. to 11:30, any dispatcher with any sense would not run a flight through there. He would spend a little bit, maybe one or two more minutes and go around it. On the other hand, if he heard everybody else going was around it, he might as well go through it."

"Do you have historical data in this also? Like what that airplane flew yesterday?"

"If you had the ability to show what that specific flight had done on previous days, that could be used in your decision making process by saying

okay, this is what happened to me in the last four to five days."

"If you had the previous history as to what that flight has done, it would go a long way toward helping you make a decision as to what you are going to do with that flight today. Because if you know if this airplane gets moved 40% of the time, then maybe you would be better off just moving it."

Another important type of historical data focuses on what happened today:

"The first flight is a good predictor of what is going to happen for the rest of the day if nothing major changes. You tend to do the same thing the rest of the day."

Thus, with appropriate integration of FACET displays with displays based on historical data, the dispatcher would be in a position to make better judgments about whether a flight is likely to be rerouted due to sector congestion or volume, and about what the nature of that reroute is likely to be.

Task-Specific Interface Design Features to Support AOCs

The final major category regarding the adaptation of FACET for use by AOCs focused on the need to develop a task-specific interface that supported Dispatch tasks. As an example of this recommendation consider the following example.

Sample Dispatch Task

As an example of potential task-specific design enhancements, consider the following walkthrough that considers how FACET's current information display capabilities could be modified to support the following specific dispatcher task.

Task: Assuming no weather, evaluate several alternative flight plans (4-D profile) that have been generated by an airline flight planning system (pre-flight) in terms of ATC constraints in the sectors through which they will pass.

Step 1: The dispatcher has his/her flight planning system generate the best N flight plans, and communicate them to the FACET. (The dispatcher may also include flight plans that were generated manually as part of this process.)

Note that, in theory, an alternative architecture would be to embed FACET's congestion predictors into a flight planning system that considered congestion as it conducted the search for desirable routes, rather than generating routes based on time and fuel and then querying FACET for information on traffic congestion along those routes.

Step 2: For each alternative flight plan, have FACET indicate whether the flight is likely to encounter "significant" ATC constraints for each of the alternative flight plans.

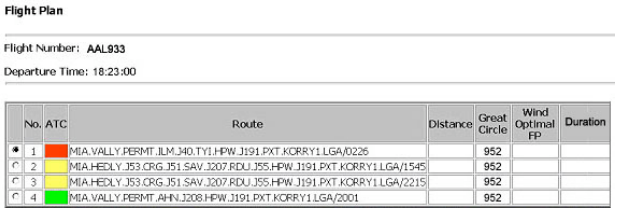
Design Issue: How should "significant" be defined? (Number of flights in a sector compared to the "maximum" for that sector? Some sector complexity measure? The likelihood that the flight will be moved?

For example, FACET could display a table in which the alternative flight plans generated in Step 1 are ordered in terms of time and/or fuel metrics generated by the airline's flight planning system. In this table, FACET could then provide some indicator regarding which alternatives are likely to encounter "significant" ATC constraints. (See the sample table below.) Note that in this table, the flight ranked highest by the airline's flight planning system (Rank 1) is color coded red, indicating that it is predicted to encounter "significant" traffic constraints, while the flight ranked fourth is marked green, indicating that it is predicted to be unlikely to encounter "significant" traffic constraints:

Green: unlikely to experience "significant" traffic congestion

Yellow: may possibly experience "significant" traffic congestion

Red: likely to experience "significant" traffic congestion


Flight Plan

Flight Number: AAL933

Departure Time: 18:23:00

	No.	ATC	Route	Distance	Great Circle	Wind Optimal FP	Duration
◉	1		MIA.VALLY.PERMT.ILM.J40.TYI.HPW.J191.PXT.KORRY1.LGA/0226		952		
○	2		MIA.HEDLY.J53.CRG.J51.SAV.J207.RDU.J55.HPW.J191.PXT.KORRY1.LGA/1545		952		
○	3		MIA.HEDLY.J53.CRG.J51.SAV.J207.RDU.J55.HPW.J191.PXT.KORRY1.LGA/2215		952		
○	4		MIA.VALLY.PERMT.AHN.J208.HPW.J191.PXT.KORRY1.LGA/2001		952		

Figure 1. Incorporating FACET traffic congestion predictions into route planning.

In this design concept for organizing FACET displays to support the flight planning task, the dispatcher first selects one of these rows using the radio button on the left, requesting a display of the pertinent information. FACET would then show all of the sectors through which that aircraft would fly, along with a map display of the route showing the sectors that would be traversed and indicating with color coding which of those sectors are predicted to have "significant" ATC constraints (see the figure below).

Design issue: To what extent should FACET make the determination that the flight will encounter "significant" ATC constraints and to what extent should FACET display the data to allow the dispatcher to make this determination?

Design Issue: Would this type of role for FACET impose excessive workload on the dispatcher? Should an approach based on alerts be used instead?

"How is it [FACET in its currently implemented form] going to help us tell the dispatcher? The dispatcher won't have time to ever look at this [FACET in its current form]; they have too many releases. The people on the West Coast have upward of 85 releases a shift to get out. The people on the East Coast have 60-70."

"The dispatcher doesn't have an easy way to take the information out of FACET [in its current form] and create a new flight plan with it. He's not going to use it. If you've got to click, click, click and you've got to move 6 screens …"

Design issue: How accurate do FACET's predictions need to be to be of value for different purposes?

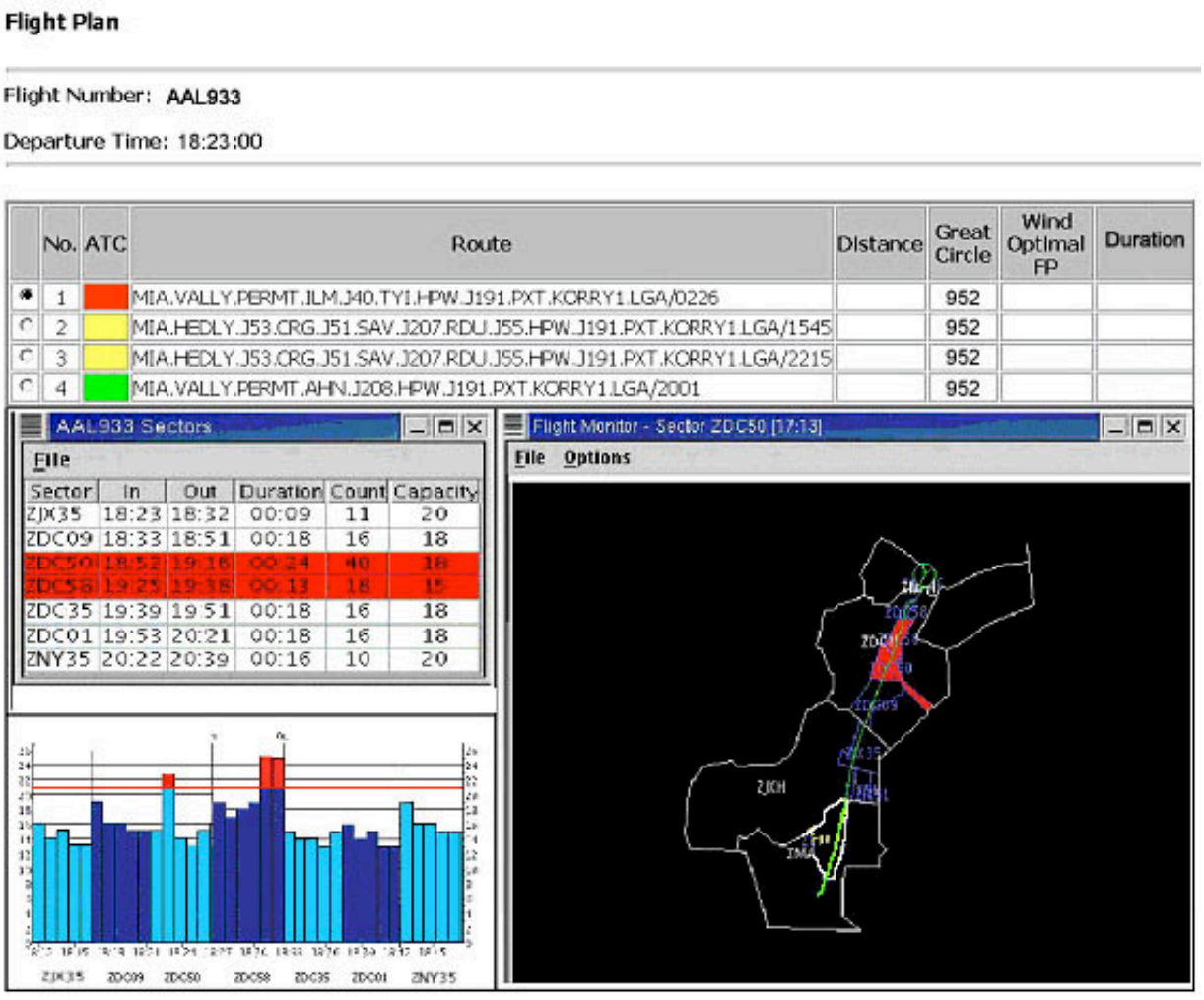


Figure 2. Providing access to additional FACET predictions in alternative formats.

Step 3: The dispatcher views the relevant data to evaluate any of the flight plans that were identified as having "significant" ATC constraints in Step 2, so that he can choose the best one from the list (or generate some alternative).

Design issue: Note that a variety of different types of data and display functions could be provided in this context. These could include weather data, the ability to move the flight along the route and view other traffic, linking of objects in the different display formats, viewing altitude profiles, expanding the map view to see traffic in nearby sectors, etc. Which ones are important to integrate into this display to support flight planning?

Step 4: The dispatcher could then iterate through Steps 1-3, using his flight planning system to generate new candidate flight plans for consideration and then looking to see what additional insights FACET provided for each of these plans. Ultimately, he could select the best flight plan and file it.

Sample Dispatch Task – Discussion

The above illustration emphasizes several points. First, FACET needs to be integrated at least indirectly with the airline's flight planning system. (One approach would be for this linkage to be accomplished via shared files.)

"It has got to be integrated … You know the guys on the floor. If they can't easily create a new route they won't use it."

"Most of the people sitting out there at the desk are looking at 4 screens. They are saturated. They have reached a point where they are not going to intake any more information."

"It could be a simple thing such as writing the file out so the flight planning system could pick it up or the flight planning system sending a file for FACET to pick up. Some way to communicate between systems. "

"I'd like to have a tie into the flight planning system that would allow me to avoid the high probability situation like I do when I plan around thunderstorms, but only if I ask it to. Allow me to make the decision as to whether that is a necessary consideration. "

Second, while many of the current FACET displays would be quite useful for tasks such as this, the design needs to provide easy access to the appropriate collections of displays to support specific tasks. ("It is not useful to the dispatcher in that manner. It has too many buttons to point and click.") For this sample task, the displays are flight-centric. In other cases, the ATC Coordinator or Dispatcher might want to look at the region around an airport, for instance, in order to think more generally about congestion in that airspace (an airspace-centric view).

Summary

This study was designed to elicit the views of airline dispatchers and ATC coordinators concerning the functions embodied in the Future ATM Concepts Evaluation Tool (FACET). While FACET was designed to assist FAA traffic managers, the focus in this work was on possible enhancements that could support the needs of air carrier personnel in airline operations centers (AOCs).

A substantial number of AOC tasks were identified in which FACET information and predictions could be potentially useful. These include predicting specific flights likely to be moved or re-routed during en route operations. Dispatch strategies that can be invoked to minimize the impacts of ATC-directed re-routes were discussed, and information required from FACET for efficient use of these strategies was considered.

Ways of combining FACET predictions with other NAS data were also considered. It was pointed out that full 4-D flight plan trajectories generated by airlines are not presently available to FAA, but that the incorporation of these data along with real-time information about traffic management initiatives (such as ground delay programs and miles-in-trail restrictions) might add materially to the accuracy of predictions concerning en route congestion. Similarly, historical data which could improve prediction accuracy is not presently utilized.

Acknowledgements

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